

Medicaid Outpatient Utilization for Waterborne Pathogenic Illness Following Hurricane Floyd

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SYNOPSIS

Objectives. Flooding provides an opportunity for epidemics of waterborne viral, protozoan, or bacterial diseases to develop in affected areas. Epidemic levels of disease may translate into higher than average levels of health services use, depending in part on help-seeking behaviors. The authors investigated whether the flooding that occurred as a result of Hurricane Floyd in September 1999 was associated with an increase in outpatient visits for waterborne diseases among Medicaid enrollees in eastern North Carolina.

Methods. Using a difference-in-differences estimation technique, the authors examined the change in outpatient visits by North Carolina Medicaid enrollees for selected waterborne diseases following the hurricane. The study focused on counties with high concentrations of hog farming that were mildly/moderately or severely affected by the hurricane, using unaffected counties and the year before the hurricane as controls.

Results. Small increases in Medicaid-covered outpatient visits were found in severely affected counties for two of the six pathogens selected for analysis, relative to unaffected counties. Larger increases in visits were found for nonspecific intestinal infections in both severely and moderately affected counties following the hurricane, relative to unaffected counties.

Conclusions. The large increase in visits for ill-defined intestinal infection is noteworthy. The relative lack of increase in visits with specific pathogenic diagnoses may be attributable, at least in part, to a number of factors, including incomplete diagnostic information provided by treating clinicians, low treatment-seeking behavior, and use of non-Medicaid-funded emergency services.

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In September 1999, Hurricane Floyd devastated the North Carolina coast, temporarily paralyzing many counties and leading to more than 50 fatalities. The strong winds and constant rain led to massive flooding that caused billions of dollars in damage. Many homes became uninhabitable or were destroyed.^{1,2} Many roads in the area were inaccessible or impassable, limiting transportation and relief efforts. The flooding led to the temporary closure of 24 water treatment plants in eastern North Carolina.³

Flooding provides an opportunity for infectious agents of viral, protozoan, or bacterial diseases to create epidemics in affected areas. The World Health Organization (WHO) notes that a combination of risk factors could lead to an increase in communicable and gastrointestinal diseases: a large magnitude hurricane, a large number of displaced people, contamination of drinking water, and poor sanitation.⁴ International organizations such as UNICEF, USAID, and WHO have researched the health effects of flooding in places of high risk. People living in developing countries experience higher rates of gastrointestinal disease due to poor sanitation and the consumption of untreated water than people in developed countries.⁵ Waterborne disease remains a major public health problem in many countries.⁶ Even in developed nations with effective water treatment facilities, diseases caused by waterborne pathogens can become epidemics, as evidenced by the *Cryptosporidium* outbreak in Milwaukee, Wisconsin, in 1993.⁷ Flooding can exacerbate the risk of illness by contaminating protected sources of treated water as well as untreated groundwater.

Most studies of disease outbreaks are targeted at specific populations experiencing gastrointestinal disease or other acute clinical symptoms. Few studies have been designed to examine long-term effects or time-related trends. We have identified only one study that has addressed waterborne disease outbreaks in the United States over a long-term period;⁸ it examined the relationship of excessive precipitation and increased rainfall with waterborne disease outbreaks throughout the United States from 1948 to 1994. The results of the study indicated that 51% of waterborne disease outbreaks followed precipitation events. Twenty-four percent of waterborne disease outbreaks resulted from contamination of surface water, and 36% resulted from groundwater contamination. The number of disease outbreaks was highest in the summer months due to intense spring rains and water runoff. The authors concluded that a statistically significant association exists between precipitation and disease outbreaks.⁸ This finding parallels conclusions drawn from investigations of specific outbreaks.

Hog farms and flooding

Hog farming is an important industry in eastern North Carolina. The number of hogs in North Carolina grew from 2.6 million in 1987 to more than 10 million by 2002.⁹ Since hog fecal waste is collected in lagoons, proper management of these reservoirs is an environmental concern due to their potential for rupturing during periods of severe environmental stress.¹⁰ Environmental protection organizations have identified hog waste as a major pollutant leading to potential health problems. Organizations such as Environmental Defense suggest that untreated hog waste can have a damag-

ing effect by polluting North Carolina's waterways and soils through waste spills and leaking waste run-off from sprayed fields.⁹ There is evidence that these effects may be concentrated in areas with large African American and low-income populations.¹¹

Fecal contaminants can include pathogens, antibiotics, and excess amounts of nitrogen and phosphorous. Each has a potentially negative impact on the environment, but pathogens are especially dangerous to human health. If animal farm lagoons are not properly treated to reduce the concentration of pathogenic organisms, the accidental release of fecal waste into the environment may contaminate well water supplies and lead to an increase in acute illnesses such as gastrointestinal or respiratory disease. It is suspected that people living close to hog farms experience a higher incidence of respiratory and gastrointestinal disease than people living farther away from hog waste operations.¹²

The potential contamination of groundwater sources by fecal waste pathogens is of great concern in eastern North Carolina because this area has a high dependence on well water for drinking.¹³ In addition, "groundwater contamination is a particular problem in eastern North Carolina because the water tables are high and many wells are shallow or unlined."¹³

Two days after Hurricane Floyd struck the North Carolina coast, hog waste lagoons ruptured, which led to the dispersal of animal waste to the groundwater, surface water, and residential well water supplies.^{11,14,15} The extensive flooding also led to the drowning of thousands of hogs and poultry. These carcasses, along with fecal waste, polluted the eastern part of the state.^{16,17} It was estimated that more than 10,000 hogs drowned.¹⁶ In addition to the contamination from hog farms and other livestock operations, the temporary shutdown of water treatment plants could have led to drinking water contamination with waterborne pathogens.

Effects of Hurricane Floyd

The purpose of this study was to examine the effect that flooding due to Hurricane Floyd had on the use of Medicaid-covered outpatient medical visits associated with waterborne pathogens. Using a difference-in-differences estimation technique, we examined the change in outpatient visits reimbursed by the North Carolina Medicaid program in counties that were mildly/moderately or severely affected by the hurricane, using unaffected counties and the year before the storm as controls. This work expands on the analyses done by present author Domino and colleagues,¹⁸ which investigated the general effect of the hurricane on total health care use and spending in the Medicaid program.

Determining the full health impact of Hurricane Floyd on the residents of eastern North Carolina has been an ongoing process. Although studies have identified the short-term effects of Hurricane Floyd,^{1,2} long-term effects need to be researched and identified. Domino et al. found a small, short-term increase in total Medicaid expenditures per enrollee in the months following the hurricane, but a larger increase in health care use up to one year after the storm; however, the pathway for this spending increase was not explored.¹⁸

Waterborne illness

Six pathogens were selected for investigation (see Methods): *Cryptosporidium*, *Giardia lamblia*, *Toxoplasma gondii*, *Helicobacter pylori*, *Mycobacterium avium*, and adenoviruses. In this section, we briefly review the literature on the prevalence and effects of these six pathogens.

Cryptosporidium. *Cryptosporidium* causes acute gastrointestinal disease that is usually mild and self-limiting but can be chronic and fatal in immunocompromised individuals or children. This protozoan is not host-specific; therefore, cows or other livestock animals can act as intermediate hosts in the transmission of *Cryptosporidium*. In 1993, the largest documented waterborne disease outbreak in U.S. history occurred in Milwaukee, Wisconsin. Public health officials identified 403,000 cases of cryptosporidiosis, with 54 deaths.⁸ *Cryptosporidium*, the sole causative agent, contaminated half of the water supply. Inadequate procedures in the treatment of the city water supply for protozoan agents such as *Cryptosporidium* led to high concentrations of this protozoan pathogen.¹⁹ Similar inadequacies in water treatment led to waterborne disease outbreaks related to *Cryptosporidium* and hepatitis A in Israel in 1988–1992.²⁰

Outbreaks of *Cryptosporidium* associated with well water have been reported in different regions of the United States involving two sources: untreated well water and wastewater treatment plants.²¹ Even underground water systems are vulnerable to contamination, especially if wells are shallow or the water table is high.²¹

G. lamblia. In the mid to late 1980s, *G. lamblia* was the agent most often implicated in waterborne disease outbreaks in the United States.²² Disease outbreaks related to the contamination of water supplies by *G. lamblia* have been reported in several regions of the United States.^{23–25} Kent et al. found that animal fecal waste in areas surrounding one reservoir tested high for *Giardia* cysts and concluded that contaminated fecal waste in close proximity to a major water supply could have been the cause of an outbreak of giardiasis.²⁴ Outbreaks of giardiasis have also resulted from flooding, heavy water runoff due to warm weather, and seasonal changes leading to the melting of ice and snow.^{22,25}

T. gondii. *T. gondii* infections are usually asymptomatic, but young children and the immunocompromised may be highly susceptible to infection. In children, chronic infection can lead to impaired vision and mental retardation. Acute symptoms of infection include fever, muscle ache, and headache. Cats are the definitive primary host for this organism, but intermediate hosts include hogs, cattle, and other livestock; infection is more prevalent in hogs than in cattle. Contamination of reservoirs used for drinking water has also been identified as a source of *T. gondii* outbreaks.²⁶ The epidemic curve of the outbreaks investigated by Bowie et al. indicates that acute infections of toxoplasmosis occurred after periods of peak rainfall.²⁶

H. pylori, M. avium, and adenoviruses. To our knowledge, nothing has been published linking these three pathogens to flooding. Brooks et al. found notable concentrations of *M. avium* along several flood plains in the eastern U.S.,²⁷ but the study did not trace these to disease outbreaks in hu-

mans. We retained these pathogens in our analyses, however, since the potential exists for exposure via contaminated water.²⁸

Adenoviruses are among the viruses that can cause upper respiratory tract infections. *H. pylori* causes acute gastrointestinal disease and, if acute symptoms are not treated, can lead to peptic ulcers and stomach cancer. Humans represent the major reservoir host for *H. pylori*, and the prevalence of this type of infection is higher in areas of poor sanitation. *M. avium* is an opportunistic pathogen that causes upper respiratory infection with clinical symptoms similar to those of tuberculosis. Poultry act as a reservoir host for *M. avium*, and this type of infection is geographically concentrated in the southeastern United States.²⁹

METHODS

We investigated whether use of outpatient services for illnesses associated with the six target pathogens increased among Medicaid enrollee in counties affected by different degrees of flooding due to Hurricane Floyd in the fall of 1999. We examined counties with high concentrations of hog farms, defined as counties in which there were more than 1,000 hogs according to the North Carolina Department of Agriculture and Consumer Services.³⁰

In the aftermath of Hurricane Floyd, the Federal Emergency Management Agency (FEMA) separated counties into four categories based on the socioeconomic impact of Hurricane Floyd: severe, moderate, minor, and not affected.³¹ It should be noted that the FEMA designations are by no means perfect indicators of the true impact of the storm; in particular, they do not provide any information on the percentage of the population affected by the storms within each county. We identified North Carolina counties with high concentrations of hog farms that received the FEMA categorizations “minor” or “moderate” (combined into a “moderately affected” category for this study) or “severe.” All but three of the moderately affected counties had high levels of hog farming, and all 14 of the severely affected counties had high levels of hog farming.

We included 96 of the 100 North Carolina counties in our analysis. Three moderately affected counties without high levels of hog farming were excluded, as was the single unaffected county in North Carolina that has prepaid contracts with health providers, limiting the availability of claims data. Of the included counties, 14 were severely affected by the storm, 27 were moderately affected, and the remaining 55 were classified as unaffected. All affected counties included in this analysis had high levels of hog farming.

We used 55 of the 56 North Carolina counties that did not experience any flooding after Hurricane Floyd as controls. In preliminary analyses, we separated these controls into counties with and without substantial hog farming, but found no statistical differences between the two groups, so we combined these counties to form one control group.

The six pathogens selected for this study met two criteria. First, the agent causing gastrointestinal illness or other acute clinical symptoms is confirmed or suspected to be waterborne. Second, each pathogen has an associated diagnostic (International Classification of Diseases, Ninth Revision [ICD-9])³³ or procedure (Current Procedural Terminology [CPT])

code.³⁴ The Candidate Contaminant List produced by the Environmental Protection Agency focuses on 11 waterborne pathogens;¹⁷ only eight of them have an associated diagnostic code or procedure code. Of the eight, codes associated with only six of the pathogens could be identified in a preliminary examination of the Medicaid dataset.

We examined North Carolina Medicaid claims data for July 1, 1998, through September 30, 1999 (pre-Hurricane Floyd) and for October 1, 1999, through September 30, 2000 (post-Hurricane Floyd) for utilization attributed to waterborne pathogens. Outpatient visits for each of the six target pathogens were identified through ICD-9 diagnosis and CPT procedure codes. Since we were at risk of substantially undercounting the number of visits with a pathogenic component by this methodology if medical providers did not use one of these codes, we also examined the number of visits that were given an ICD-9 diagnosis of “ill-defined intestinal infection.”

Data were aggregated to the county-month level, yielding dependent variables that indicated the total number of visits in each county and each month. We used difference-in-differences ordinary least squares regression models, as described below, to compare counties severely and moderately affected by flooding with counties unaffected by flooding. Dependent variables were left in their original form rather than logged, both because county-level visit distributions were less likely to be skewed than individual-level data and because Wooldridge tests³⁵ indicated that the linear form gave a better fit with the data for all dependent variables reported here.

The following variables were employed in the analysis:

- *Dependent variables:* The dependent variable was the number of outpatient Medicaid visits in each county with a specific procedure or diagnostic code associated with each pathogenic condition in each month.
- *FEMA category:* Dummy variables indicating that the county was severely affected or moderately affected by flooding were created. We used these variables to iso-

late the post-hurricane effects in these two county types (see *Interaction variables* below). The use of county fixed effects, however, precluded the use of these time-invariant variables in the models. That is, the FEMA category indicators were linearly dependent on the county fixed effects and, thus, were not used uninteracted in the models. The interacted term retained its proper meaning since the county fixed effects stood in for the FEMA category indicators, actually allowing more heterogeneity across counties within a category.

- *Post-Hurricane Floyd:* This dummy variable indicated the period from October 1, 1999, to September 30, 2000.
- *Interaction:* Interaction variables were created to identify the combined effect of the post-Hurricane Floyd variable and the FEMA category variable. The coefficient on these variables indicates the effect of the storm on the level of utilization in these counties.

Regression models were weighted by the number of Medicaid enrollees in each county in each month during the two-year time period of this study. We included a linear time trend to control for secular trends statewide. The difference-in-differences approach used in these regression models controls both for trends in the number of visits in all counties before and after the hurricane and for the ways the counties may have been different before the hurricane, if those differences did not change over time. This leaves the interaction variable (the “difference in differences” variable) to pick up differences that can reasonably be attributed to effects of the flooding. Robust standard errors (SEs) are reported.

RESULTS

The average number of Medicaid outpatient visits resulting in a pathogenic diagnosis per county during the study time period, weighted by the number of Medicaid enrollees in each county and month, is given in Table 1. There was no

Table 1. Mean number of monthly outpatient visits by Medicaid enrollees before and after Hurricane Floyd, weighted by the number of Medicaid enrollees in county, by pathogenic diagnosis

Pathogenic diagnosis	Severely affected counties with high concentrations of hog farms (n=14)		Moderately affected counties with high concentration of hog farms (n=27)		Unaffected counties (n=55)	
	Pre-Floyd (n=210)	Post-Floyd (n=168)	Pre-Floyd (n=405)	Post-Floyd (n=324)	Pre-Floyd (n=825)	Post-Floyd (n=660)
<i>Cryptosporidium</i>	0.16	0.11	0.33	0.45	0.71	0.82
<i>G. lamblia</i>	0.03	0.01	0.003	0	0.12	0.10
<i>M. avium</i>	1.79	1.88	2.15	1.87	1.62	1.44
<i>H. pylori</i>	4.81	4.78	8.73	8.43	5.48	5.97
<i>T. gondii</i>	0.98	0.97	3.78	3.36	1.47	1.15
Adenovirus	0.03	0.20	0.01	0.01	0.11	0.11
Ill-defined infection	5.12	11.00	7.90	15.17	10.15	11.16
Unweighted Medicaid population	10,869	11,067	9,180	9,471	8,053	8,356

Table 2. Regression results on the number of outpatient visits per county for each pathogenic diagnosis for each month

Variable	Regression coefficient (robust standard error)						
	Crypto-sporidium	<i>G. lamblia</i>	<i>M. avium</i>	<i>H. pylori</i>	<i>T. gondii</i>	Adenovirus	Ill-defined infection
Post-Floyd* severely affected	-0.089 (0.111)	0.017 (0.036)	0.06 (0.22)	0.13 (0.42)	0.44 ^a (0.20)	0.227 ^b (0.080)	4.80 ^b (1.70)
Post-Floyd* moderately affected	0.003 (0.123)	0.024 (0.025)	-0.13 (0.21)	-0.82 (0.50)	-0.07 (0.32)	0.010 (0.044)	6.21 ^b (1.47)
Post-Floyd indicator	-0.031 (0.133)	-0.058 (0.043)	0.24 (0.19)	-0.83 ^a (0.42)	-0.59 ^a (0.24)	-0.133 ^b (0.070)	1.09 (1.02)
Time trend	0.00040 (0.00028)	0.000085 (0.000076)	-0.00110 ^b (0.00040)	0.0035 ^b (0.0010)	0.00074 (0.00057)	0.00035 ^b (0.00013)	-0.0002 (0.0022)
R ²	0.58	0.39	0.71	0.89	0.84	0.22	0.74

NOTE: N52,592 for all regression models. Models were weighted by the Medicaid enrollment in each county month. All models were controlled for county fixed effects.

^ap<0.05.

^bp<0.01.

clear increase in visits for each pathogen-specific diagnosis from the pre-Floyd period to the post-Floyd period for all six pathogens. Medicaid outpatient visits for ill-identified pathogen-related illness, however, were substantially higher after September 1999.

Results of the regression analyses are reported in Table 2. The key variables in all models are the interactions between the post-Floyd indicator and the FEMA severity designations. These variables can be interpreted as the effect of the hurricane on the level of utilization that would have been predicted in its absence. We found a statistically significant increase in outpatient visits only for *T. gondii* and adenoviruses following Hurricane Floyd in severely affected counties, as compared to non-affected counties. The magnitude of both effects is small, indicating on average less than one extra outpatient visit each month in each severely affected county for these pathogens. No relative increase in outpatient visits was detected for any of the other specific pathogens, nor was any increase observed for any of the pathogens in moderately affected as compared with non-affected counties.

The last column in Table 2 shows a large, significant increase in outpatient visits for ill-defined intestinal infections in both severely and moderately affected counties as compared to unaffected counties.

Due to the large number of counties with no visits for each of the pathogens in certain months, we reran all models as two-part models (not shown); this technique separated predictors of having any visits from predictors of the number of visits for counties with one or more visits. We found that for two of the pathogens with significant effects of the hurricane (adenoviruses and ill-defined conditions), the hurricane caused increases in the level of use, conditional on positive use, while for three of the conditions (*T. gondii*, *H. pylori*, and ill-defined conditions), the hurricane increased

the likelihood that the affected counties had one or more visits.

DISCUSSION

Epidemic levels of disease caused by waterborne pathogens may translate into higher than average levels of health services use, depending in part on affected individuals' health care-seeking behavior. The several steps along the chain from above-normal levels of pathogens to greater use of the medical system have not been well studied. Infected individuals may increase their use of health care services depending on the presence or severity of their symptoms, their access to the health care sector, and their expectations about the effect of health care visits on their symptoms. It is unclear *a priori* whether greater risk of pathogenic exposure translates into greater use of the health care system.

A study by Curriero et al. suggests that weather phenomena resulting in increased amounts of rainfall and precipitation lead to an increased incidence of waterborne pathogen-related diseases.⁸ Hurricane Floyd devastated the North Carolina coast, resulting in the massive flooding of many counties in the eastern part of the state, but did not yield a large overall increase among the Medicaid population in outpatient visits for each of the six specific pathogens investigated in this study.

Small increases in Medicaid-covered outpatient visits with diagnoses of *T. gondii* and adenoviruses were detected in severely affected counties as compared to non-affected counties after the storm. It is interesting that one of the two pathogens with increased utilization is one for which there is some ambiguity with regard to the method of transmission.³¹

We did observe a larger, significant increase in the num-

ber of visits with a diagnosis of ill-defined intestinal infection in both severely and moderately affected counties after the hurricane as compared to non-affected counties. We observed an average increase of just under five visits per county each month for severely affected counties and an average of just over six visits per county each month for moderately affected counties relative to the unaffected control counties. Coupled with the finding by Domino et al. that Medicaid enrollment decreased after Hurricane Floyd in severely affected counties as compared to unaffected control counties,⁸ this finding indicates a real increase in medical services use as a result of the storm. However, the relative magnitude of the increase is small, accounting for less than 1% of the total increase in outpatient visits for any purpose observed as a result of the storm.¹⁸

Several factors may have contributed to the lack of increase in specific pathogenic diagnoses following the hurricane. Providers may not have recorded information on specific pathogenic sources of gastrointestinal infections through the use of diagnostic codes. This may have been due to the lack of definitive information on the specific pathogen responsible for GI symptoms or to the fact that fee-for-service reimbursement for medical visits is generally based on procedure codes, not diagnosis codes, and thus accurate diagnostic information is not rewarded. Although all pathogens examined in this analysis are associated with both diagnostic and procedure codes, under-use of specific pathogenic diagnostic codes would have resulted in an undercount of the number of outpatient visits in our data. Additionally, we cannot rule out the possibility that an increased sensitivity on behalf of Medicaid providers to GI or respiratory complaints following the hurricane may explain these results. If providers were more likely to code visits for ill-defined intestinal infections after the flooding than before the flooding, for example, then we might have observed an artificially high level of visits with these indications.

Our data do not permit us to examine whether the small increases in medical service utilization for these pathogens can be explained by low treatment-seeking behavior. We also do not know whether residents who were dependent on well water or groundwater took precautionary steps to disinfect their water supplies. Finally, the inability to track the exact location of individuals in this dataset after the storm may have contributed to under-reporting. If people who lost homes or were otherwise displaced from areas designated as severely or moderately affected sought services in non-affected counties, our findings would underestimate the true level of utilization. Domino et al. found no evidence of increased out-of-county receipt of health services after the flooding, but it is possible that non-Medicaid-funded temporary emergency services were substituted for visits recorded in Medicaid data and that, as a result, our results understate the total increase in visits.¹⁸

CONCLUSION

In the United States, outbreaks of disease from waterborne pathogens usually occur due to sanitation system failures or seasonal rainfall with excessive runoff.⁸ The disruptive effect of Hurricane Floyd on the infrastructure of eastern North Carolina, excessive flooding, the rupturing of hog waste

lagoons, and the temporary shutdown of water treatment plants led to a high degree of environmental contamination by waterborne pathogens and other pollutants. The finding of virtually no increase in outpatient visits with a pathogenic indication in affected counties as compared to non-affected control counties indicates that the effect of this environmental hazard did not trickle down to the medical care system in expected ways. The modest increase in visits for ill-defined intestinal infections, however, does indicate some increase in utilization of the medical system by Medicaid enrollees. Although waterborne pathogens cause short-term illness, long-term complications can also arise. Additional studies assessing the long-term health impact of Hurricane Floyd, especially related to waterborne pathogens, will increase the available knowledge regarding the connection between natural disasters, disease outbreaks, and their effects on the medical care system.

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